Refinancing Frictions, Mortgage Pricing and Redistribution

David Berger (Duke)
Konstantin Milbradt (Northwestern University)
Fabrice Tourre (Copenhagen Business School)
Joseph Vavra (University of Chicago)

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Background and Research Questions

- Background 1:
  - households refinance fixed-rate mortgages sub-optimally
  - large cross-sectional differences in this sub-optimality

- Background 2:
  - Institutional setting limits price discrimination by lenders:
    - legal restrictions
    - TBA market

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- This paper: consequences for equilibrium mortgage pricing
  - Quantify cross-subsidies from mortgage market pooling
  - Distributional effects of various mortgage reforms:
    - new contract designs: auto-refinancing mortgages
    - new contract designs: lock-up periods
    - info disclosure requirements/rise of fintech

Road map

Mortgage refinancing decisions

Markov perfect equilibrium with homogeneous households

Heterogeneous Households

Quantitative implications

Conclusion

Model setup

Households

- continuous time
- continuum of measure 1, risk-neutral, discount rate ρ
- \$1 notional fixed rate mortgage, coupon c_t
- *non-strategic* prepayment at rate ν (move, amortization, divorce)
- option to refinance at any time
- frictions
  - make decisions at discrete points in times arriving with **attention rate** χ
  - upon refinancing, pay **upfront closing cost** ψ

Mortgage rates $m_t = m(x_t)$

- x_t (diffusion and driving process) latent state for term structure model $r(x_t)$
- mortgage rate $m(x_t)$ taken as given by households
- at origination or refinancing time τ, $dc_\tau = m(x_\tau) - c_{\tau-}$

Optimal household behavior

Household problem

- choose optimal refinancing times...
- ... in order to minimize expected future mortgage-related costs
- With up-front cost $\psi > 0$
  - Households follow one-sided Ss refi rule w/ gap threshold θ
  - Inattention reduces θ (i.e. up-front costs less important for decisions)
- With no up-front costs:
  - $\theta = 0$

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Mortgage rates in equilibrium (Homogenous HHs / Separating)

Mortgage investors

- capital elastically supplied by risk-neutral investors that discount at $r_t = r(x_t)$
- wedge f between coupon paid by households and cash-flow received by investors
  - G-fees, servicing fees
- mortgage origination costs incurred by lenders recouped via
  - **upfront closing costs** ψ paid by households (influences optimal refinancing)
  - **gain on sale** π realized in secondary MBS market
- perfect competition in mortgage lending: origination costs $\pi + \psi$
- mortgage price (value to investors) $P(x, c; \chi)$ if household has attention rate χ
- Equilibrium "break-even" condition at origination: $P(x, m(x); \chi) = 1 + \pi$

Equilibrium concept: Markov perfect equilibrium ("MPE")

Results in the paper

Equilibrium

- Prove existence, uniqueness for homogeneous setup with no upfront closing costs ($\psi = 0$)

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Key assumption for remainder analysis

- no upfront closing costs faced by households when refinancing ($\psi = 0$)
  - **justification**: Numerical results that up-front costs don't matter much: affect "small" refis which have little impact on valuation, whereas inattention affects "big" refis which have large impact on valuation
  - supported by data: 80% of origination costs financed via higher coupons, not paid upfront
  - $\Rightarrow$ key friction in our paper: **inattention**

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Empirics

- panel data on households' refinancing allows us to reject homogeneity assumption
- difficult for conforming mortgage originators to price-discriminate (legal restrictions + market structure) [institutional detail]
- $\Rightarrow$ assume cross-sectional attention distribution $H(\chi)$, and investors cannot screen on χ

Mortgage rates with heterogeneous households

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Mortgage pricing

- What investors care about is (endogenous) attention distribution G_t of refinancing mortgages not (exogenous) population distribution H
- state variable now includes joint density over coupons c and attention types χ
- difficult infinite-dimensional problem
- **approximate MPE**: investors exhibit "bounded rationality"
  - Know that distribution of refinancers G_t differs from that in population H but...
  - price as if attention density for newly originated mortgages only depends on latent state x
  - consequence: investors break-even on average for each x but not path-by-path t [pricing errors]

Theoretical Results

Existence/Uniqueness results in paper

- when $r(x_t)$ is one-factor model, there exists a *unique* (monotone) Approximate Pooling MPE if the "candidate" $m(x)$ is monotone

How does cross-sectional heterogeneity in χ affect equilibrium mortgage rates?

- mortgage pool price $\bar{P}_G$ for unconditional ergodic $G(\chi)$ satisfies

$$\bar{P}_G(x,c) = P(x,c;\bar{\chi}_G) - \mathbb{E}_x\left[\int_0^\tau e^{-\left(\int_0^t r(x_s)ds\right)} \mathbb{1}_{\{m(x_t)\leq c\}} \mathbb{C}\mathrm{ov}^G\left(\chi, P(x_t,c;\chi)\right) dt\right]$$

  - mortgages priced as if homogeneous pool with attention $\bar{\chi}_G$...
  - ... with negative covariance adjustment in typical situation where value of mortgage declines in
  - ... in which case $m(x;G) \leq m(x;\bar{\chi}_G)$

- Heterogeneity lowers mortgage rates at origination!

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Measuring inattention in the data

CRISM

- monthly data set following 232k individuals from 2005m6 to 2017m12
- unit of observation: month-household
- observables: monthly refi, cash-out, purchase, FICO, loan balance, LTV (constructed via local price indeces), mortgage rate gap

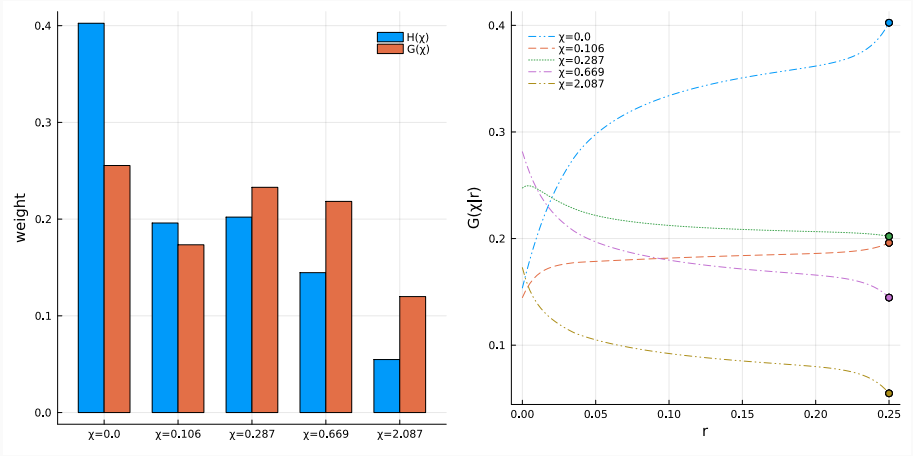
SFLP (Fannie Mae)

- monthly data set following 250k mortgages from 2000m1 to 2021m12
- unit of observation: month-mortgage
- observables: monthly prepayment, loan balance, mortgage rate gap, initial FICO, initial LTV

Clustering Algorithm

MLE for N groups delivers a non-strategic “move” rate + attention rates by group

Origination distribution G



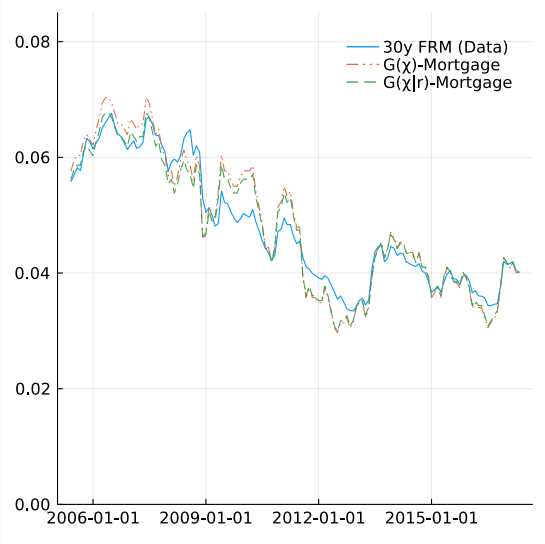
- Average attention rate in the population $\mathbb{E}^H[\chi] = 19\%$
- Average attention rate for newly originated mortgages $\mathbb{E}^G[\chi] = 59\%$

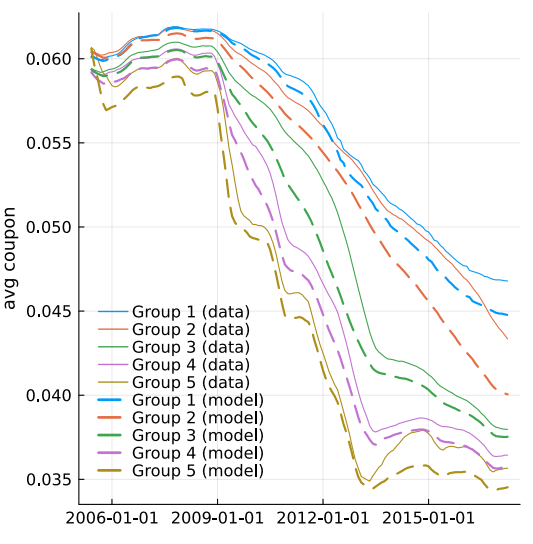
Calibration/estimation of other model parameters

- CIR model of short rates (MLE) $\rightarrow (\mu, \kappa, \sigma)$
- non-strategic prepay rate (from clustering algo) $+$ amortization rate $\rightarrow \nu$
- G-fee as wedge between mortgage coupon and investor cash flows $\rightarrow f$
- mortgage origination costs from Zhang (2022) $\rightarrow \psi + \pi$
- upfront closing costs rolled into higher rates $\rightarrow \psi = 0$, but $\theta = 25bps$

Parameter	Value	Interpretation
μ	3.5%	long run mean short rate
κ	0.13	speed of mean reversion
σ	6%	volatility
ν	7.1%	non-strategic prepay $+$ amortization rate
f	0.45%	G-fees
π	3.7%	gain on sale (cost rolled into higher rates)
ψ	0%	upfront closing costs

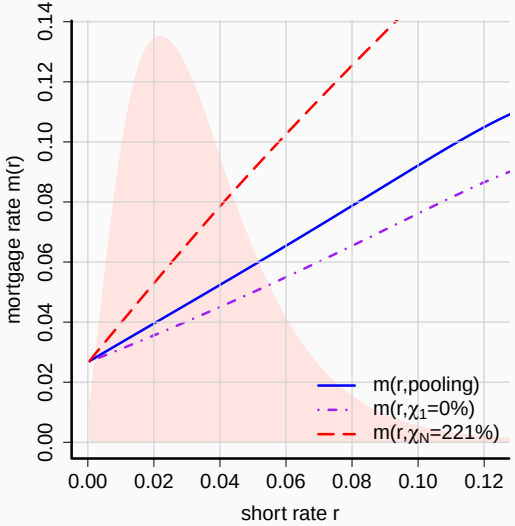
Model validation: Prices and Quantities

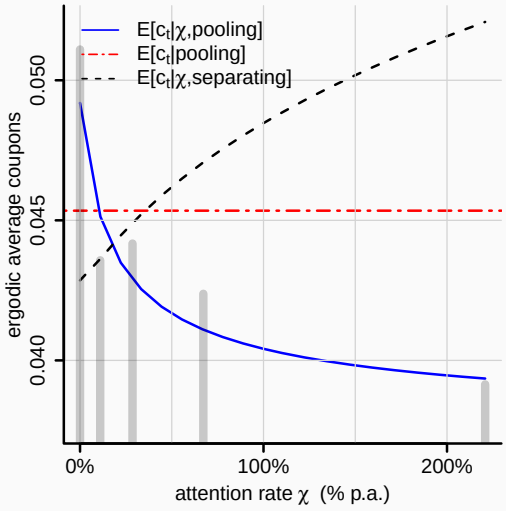




Equilibrium mortgage rates and redistribution

[Table]





Ergodic Redistribution: PE and GE

[Expanded Table]

- Both PE and GE forces important but with significant heterogeneity
  - Fastest HHs pay 38 bps p.a. more than avg. HH, and 60 bps more than in separating eqm
  - Slowest HHs pay 62 bps p.a. less than avg. HH, and 121 bps less than in separating eqm

Group	PE (bps p.a.)	GE (bps p.a.)	total (bps p.a.)
1 (slowest)	38	23	60
2	-7	17	10
3	-28	7	-22
4	-46	-13	-58
5 (fastest)	-62	-59	-121

- Explore various covariates in paper (although covariate data quality not great)
- Suggests regressive cross-subsidies: poor, minority, less educated, low FICO borrowers pay more

Reducing frictions via contract design: automatic refinancing

Households' refinancing mistakes

- Existing literature: welfare gains achievable via automatically refinancing mortgages
- But literature not factoring in equilibrium response

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Automatically refinancing mortgages ("Auto-RM")

- Smart contract: no origination costs upon "rate reset", only upon new mortgage
- when no gain-on-sale $\pi = 0$, equivalent to homogeneous MPE with $\chi = +\infty$

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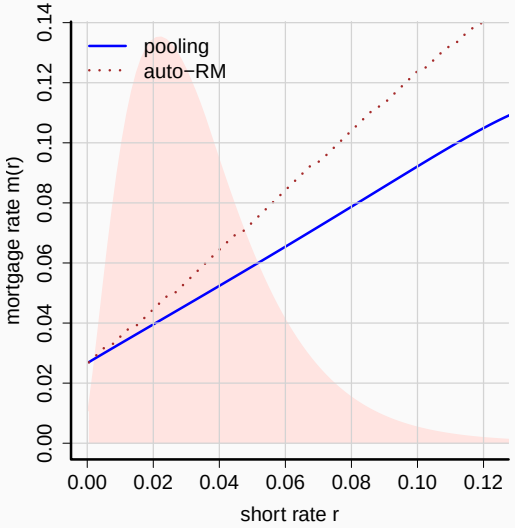
Properties of Auto-RM contract

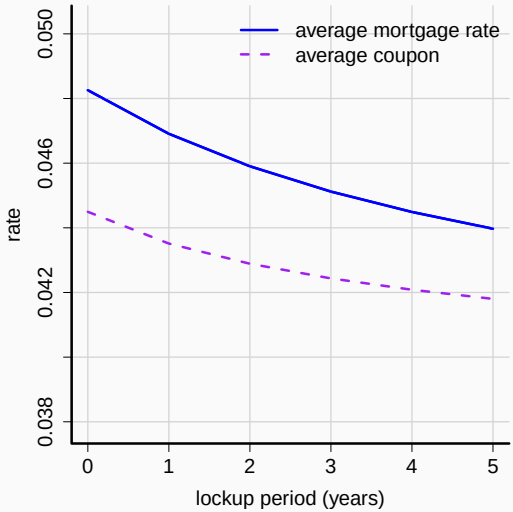
- Auto-RM more costly than ARM: $m(x; \infty) > r(x) + f$ for all latent state x
- "unravelling": if Auto-RM made available, all households – in the absence of other financial frictions – eventually migrate to it

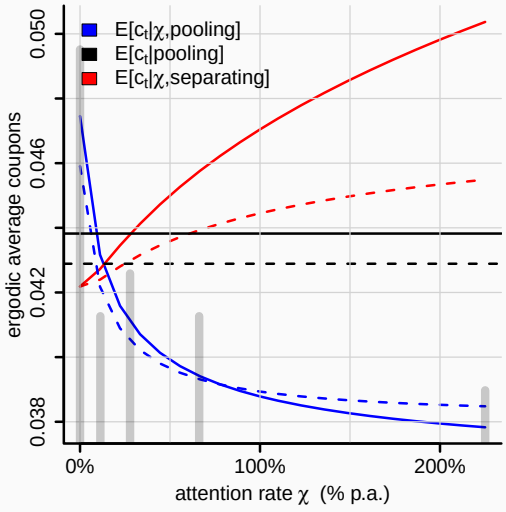
Automatically refinancing mortgages: pricing



- Auto-RM leads to significantly higher initial rates (**90bps** on average), even though it "saves" on closing costs
  - Without heterogeneity shrinks to 13bps
- Cross-subsidies disappear
- Avg coupon:
  - keeping mortgage rates constant, absent refi frictions, everyone gains
  - with eqm mortgage rates, least attentive gain, most attentive lose
- [DTI constraints] would force $\sim$ **16%** of borrowers to select smaller homes / smaller initial mortgage balance

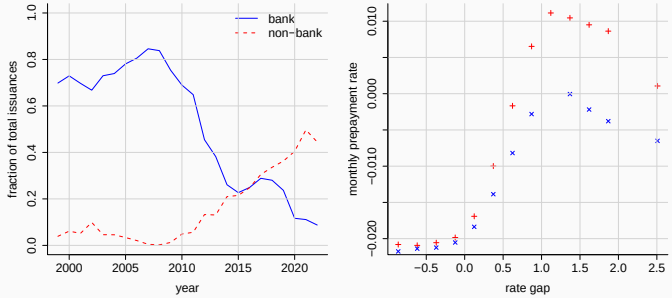
Reducing mortgage inequality via contract design: lockup periods





Information Disclosure/The rise of non-bank mortgage lenders

- RCT in Ireland found info disclosure can increase refi by 100bp/month
- Coincidentally, similar to difference in refi propensity for fintech loans, which have grow over time



- Effect on mortgage rates of 100bp/month attention? Rise by 35bp

Open questions

Separating financial frictions from behavioral frictions

- For policy evaluation, it can be important to separate financial frictions (too low FICO, too high LTV, unemployed) from behavioral frictions (financially unsophisticated, distracted)
  - Denmark allows refinancing (as long as not cash-out) without income verification
  - How much would rates and redistribution change in the US with this policy?
  - How much could financial literacy programs change the equilibrium?
    - Unintended GE consequence: if programs help only some people become more attentive, those left behind even worse off

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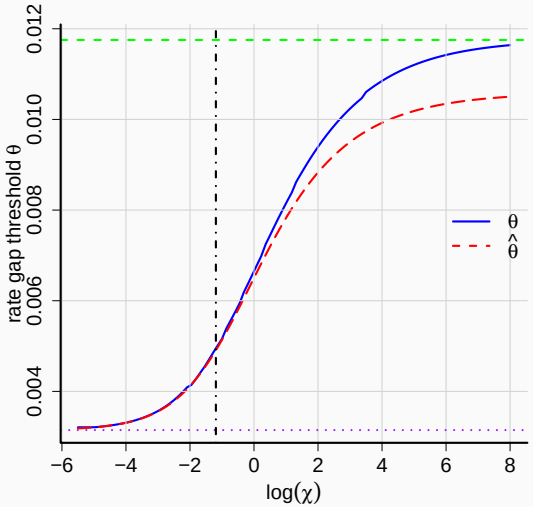
- Tractable mortgage pricing model capturing cross-sectional differences in attention
  - Novel results for household behavior and equilibrium
  - Systematic study of inattention friction and its impact onto equilibrium outcomes
- Measure distribution of attention in large panel of US borrowers
- Substantial cross-subsidies arising from pooling MPE
  - regressive cross-subsidies
  - direction opposite that from credit guarantee scheme
- Policy analysis and model counterfactuals
  - Financial literacy programs will hurt those that are “untreated”
  - Automatically refinancing mortgages with large equilibrium effects
  - Mortgages with lockup periods promising contract to help reduce mortgage inequality
  - Recent rise of non-bank lending has caused increase in mortgage interest rates

Road map

Appendices

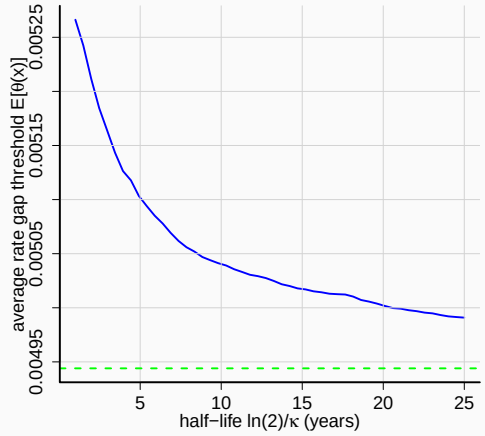


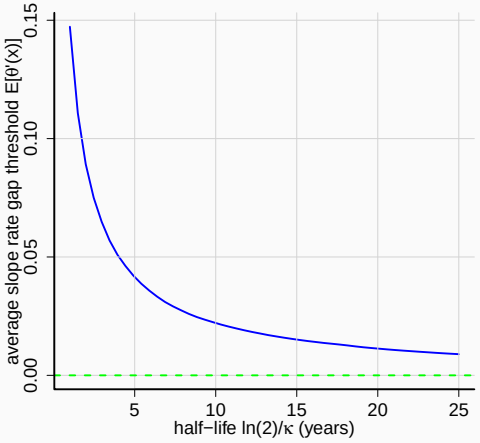
- blue solid (red dash) line: rate gap threshold θ (approximation $\hat{\theta}$)
- data: $\chi \approx 30\%$
- **Key insight:** Upfront costs become less important in the presence of inattention
- Agarwal et al (2016), Fuster et al (2019) revisited:
  - are households refinancing too early?
  - are households refinancing optimally, subject to attention friction?

Mean reverting rates: state dependent policies

[Back]

- mortgage rate follows OU process: $dm_t = \kappa(\bar{m} - m_t)dt + \sigma dB_t$
- optimal rate gap threshold now state-dependent: $\theta(x)$





Institutional details – conforming mortgage market

[Back]

Origination and securitization process

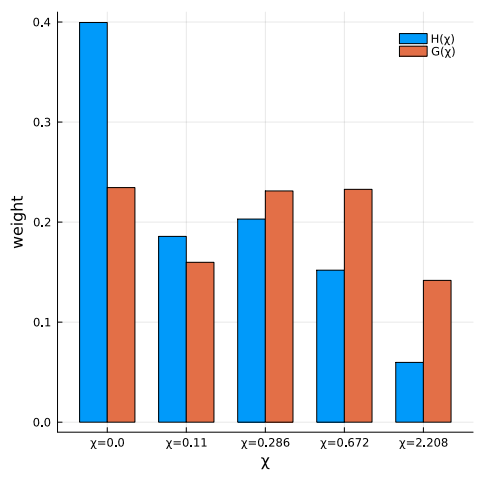
- Originator extends mortgage to borrower
- Originator then hedges
  - rate risk via the to-be-announced ("TBA") market
  - fallout risk via swaptions or other derivatives
- Once a pool of loans is assembled
  - loans delivered to the agency (Fannie or Freddie) vs. MBS security
  - originator delivers MBS into TBA contract
  - originator either retains or sells mortgage servicing right ("MSR")

TBA contract

- effectively, a forward contract
- term (e.g. 30 years), issuer (e.g. Fannie), coupon (e.g. 2.5%, in 50bps increments), settlement month, notional, price
- no specification of exact pool to be delivered $\Rightarrow$ cheapest-to-deliver
- SIFMA "good delivery" guidelines

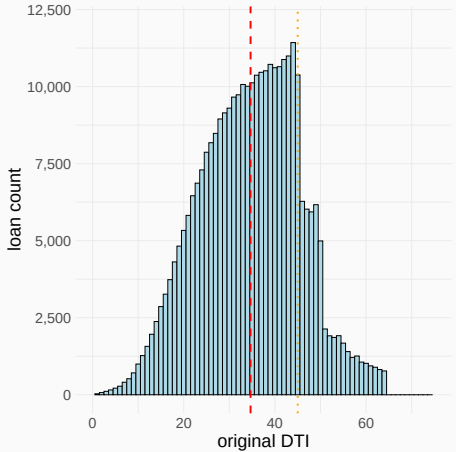
Unconditional origination distribution $G(\chi)$

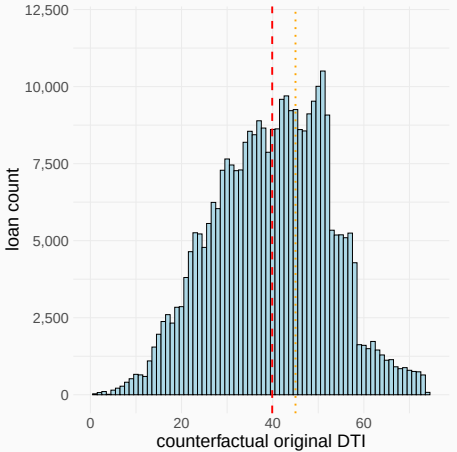
[Back]



DTI and counterfactual DTI at origination

[Back]





General framework – labor market application

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Workers — value function $V(x, w)$

- risk-averse and cannot save
- productivity $x_{i,t}$ (Itô process, idiosyncratic shocks), fixed wage rate w_{it}
- outside offers at rate χ ("loyalty"), cross-sectional distribution $H(\chi)$

Firm — match value $\Pi(x, w; \chi)$ conditional on worker type

- offers competitive wage s.t.
  1. no discrimination (i.e. offer not contingent on χ)
  2. maximal insurance given workers outside offer (i.e. fixed wage contract)
  3. breaks even given distribution of job applicant types $G(\chi)$
- worker-firm pairs separate at unconditional rate ν

MPE — pooling equilibrium wage rate for new workers $\mathcal{W}(x)$

- cross-subsidies between "loyal" and "on-the-job hunting" workers
- at separation, wage losses even without firm-specific human capital

Krussel-Smith (1998) Procedure (1)

1. Summarize the cross-sectional distribution f_t by a small number of moments that are good summary statistics
   - With finite types, summarize fraction of households with positive rate gap $\Phi_{i,t} := 1 - F_t(m_t, \chi_i)$ so that
   $$g_t(\chi_i; m_t) = \frac{(\nu + \chi_i \Phi_{i,t}) h_i}{\sum_{j \leq k} (\nu + \chi_j \Phi_{j,t}) h_j}$$

2. Next, postulate dynamics $d\Phi_{i,t} = \mu_{\Phi,i}\left(x_t, \vec{\Phi}_t\right) dt$ for a set of k unknown drift functions and solve for prices
   - Guess functions m and $\mu_{\Phi,i}$, solve Feynman-Kac equation for type specific price function $P\left(x, \vec{\Phi}; \chi\right)$, then integrate over distribution g_t to compute pool price $\bar{P}$ for all states $\left(x, \vec{\Phi}\right)$

3. Update mortgage rate function m by solving $\mathbb{E}^G\left[P\left(x, \vec{\Phi}, m\left(x, \vec{\Phi}\right); \chi\right)\right] = 1 + \pi$

4. Use simulated system to update drift functions

Krussel-Smith (1998) Procedure (2)

[Back]

- KS logic relies on dynamics of $\vec{\Phi}_t$ can be well-described by first-order Markov process
  - this is unfortunately not the case with closer look at $d\Phi_{i,t}$

$$\begin{aligned} d\Phi_{i,t} =& d\left(\int_{m_t}^{+\infty} f_t\left(c, \chi_i\right) dc\right) \\ =& -\left(\nu + \chi_i\right) \Phi_{i,t} dt - \left[\partial_S \left(F_t(m(S), \chi_i)\right) \cdot \mu_S + \frac{1}{2} \text{tr}\left(\sigma_S' \partial_{SS'} \left(F_t(m(S), \chi_i)\right) \sigma_S\right)\right] dt \\ & - \sigma_S' \partial_S \left(F_t(m(S), \chi_i)\right) dZ_t \end{aligned}$$

  Second term introduces distortions arising from aggregate shocks and their impact on the fraction of households with positive rate gaps

- KS approach also relies on idea that absent aggregate shocks dynamics system has stationary cross-sectional distribution and does not depart too much from it in the presence of *small* aggregate shocks
  - here this distribution is degenerate absent aggregate shocks

Breaking down the Redistribution

[Back]

	Unconditional Pricing			Conditional Pricing		
Group	PE (bps p.a.)	GE (bps p.a.)	total (bps p.a.)	PE (bps p.a.)	GE (bps p.a.)	total (bps p.a.)
1 (slowest)	38	23	60	35	19	54
2	-7	17	10	-6	13	7
3	-28	7	-22	-26	3	-24
4	-46	-13	-58	-43	-17	-59
5 (fastest)	-62	-59	-121	-58	-63	-122

Table 1: Synthetic & Backfilled, threshold 25*bps*: This table shows how mortgage coupons vary with attention when fixing prices (PE) as well as compared to an alternative separating equilibrium (GE) under unconditional and conditional pricing. The PE column computes $\mathbb{E}[c_t|\chi, \text{pooling}]$-$\mathbb{E}[c_t|\text{pooling}]$ and the GE column computes $\mathbb{E}[c_t|\text{pooling}]$ - $\mathbb{E}[c_t|\chi, \text{separating}]$ for each borrower type χ. A negative value indicates that a borrower receives subsidies and a positive value indicates that a borrower is taxed in the pooling equilibrium.